Welcome to
NASA Applied Remote Sensing Training (ARSET)
Webinar Series

Introduction to Remote Sensing Data for Water Resources Management

Course Dates: October 17, 24, 31 November 7, 14
Time: 8-9 AM EDT/EST; 1-2 p.m. EDT/EST

ARSET

Applied Remote SEnsing Training
A project of NASA Applied Sciences

Outline

- About ARSET
- Earth's Water Resources
- ARSET Course Structure
- Week 1 : Overview of NASA Remote Sensing and Earth Systems Modeling Data for Water Resources Management

Applied Remote SEnsing Training (ARSET)

A NASA Applied Sciences Program

NASA Earth Science
Applied Sciences Program

Applications to Decision Making: Eight Thematic Areas

Agricultural Efficiency

Air Quality

Climate

Disaster Management

Ecological Forecasting

Public Health

Water Resources

ARSET

Objectives

- Provide end-users with **professional technical workshops**
- Build long term partnerships with communities and institutions in the public and private sectors.

Online and hands-on courses:

- **Who:** policy makers, environmental managers, modelers and other professionals in the public and private sectors.

  Where: U.S and internationally
- **When**: throughout the year. Check websites.
- Do NOT require prior remote- sensing background.
- Presentations and hands-on guided computer exercises on how to access, interpret and use NASA satellite images for decision-support.

Recent ARSET Courses: Water Resources/Flooding

- Cartagena, Colombia, hands-on
  November 2011, Precipitation, Flooding

- University of Oklahoma, National Weather Center, hands-on
  June 2012

- First online course
  Fall 2012
  Precip/Flooding/Drought

- Second Online course
  Jan/Feb 2013
  Snow Products

- World Bank, DC, hands-on
  March 2013
  Flooding Applications

Attendees of the NASA water resources training at the University of Oklahoma on June 19-20, with course instructors Amita Mehta and Ana Prados. Preliminary end-user feedback included a) interest in follow-on advanced/online courses and b) additional topics in land products, e.g. ET and Landsat.

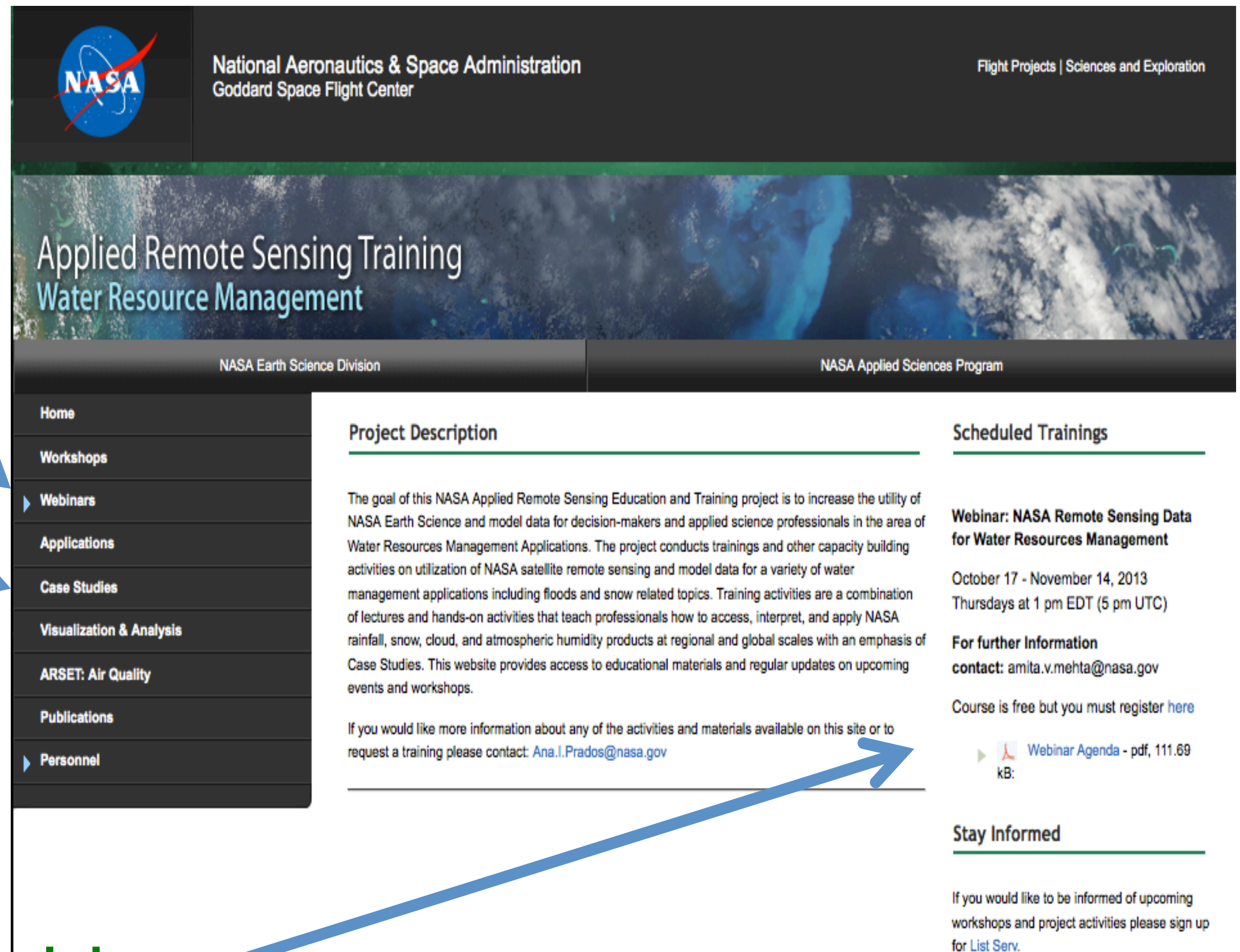
Who Can Benefit from ARSET Courses?

- **Public Sector:** Local, state, federal, international regulatory agencies, project managers, health and disaster management agencies, World Bank, United Nations
- **Private Sector:** industry, NGOs, consultants, and other organizations involved in capacity building
- **Scientists/Technical Experts**: Meteorologists, Modelers, Hydrologists, Agriculture, Health and Disaster Researchers

http://water.gsfc.nasa.gov/

Modules in English and Spanish

Case Studies



Upcoming trainings

Sign-up to listserv

Your Course Instructors

- Amita Mehta (ARSET) amita.v.mehta@nasa.gov
- Brock Blevins (ARSET) bblevins37@gmail.com
- Evan Johnson (ARSET) evan.r.johnson@nasa.gov

Guest Speakers:

- John Bolten (NASA/GSFC) john.bolten@nasa.gov

Other Contributions to this Course

Spanish Translation: David Barbato (ARSET)

General Inquiries/questions about ARSET:

Ana I. Prados (ARSET) apradoss@umbc.edu

Course Structure

Course Objectives

- Provide overview of measurements/calculation of Water Cycle Components: focus on fresh water over land
- Introduce web-tools for data access, analysis, and imaging
- Show examples of data applications
- Prerequisite for advanced ARSET Trainings

Webinar Course Structure

- One lecture per week – every Thursday from 17 October to 14 November (8-9 AM EDT/EST and 1-2 p.m. EDT/EST)

- Webinar presentations can be found at: http://water.gsfc.nasa.gov/webinars/

- Two assignments (after Week-2 and Week-4)

- Q/A : 15 minutes following each lecture and/or by email (amita.v.mehta@nasa.gov)

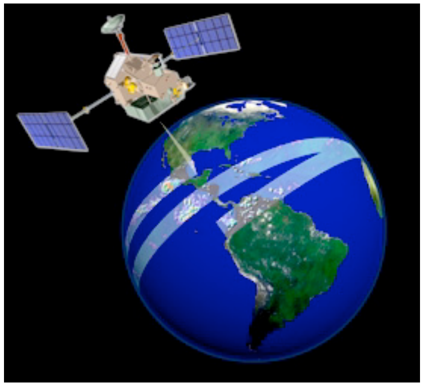
Certificates of Completion:
You must attend all 5 live sessions
You must submit 2 homework assignments

For Webinar Recording Link :

Contact : Marines Martins
Email: marines.martins@ssaihq.com

Course Outline

Week 1

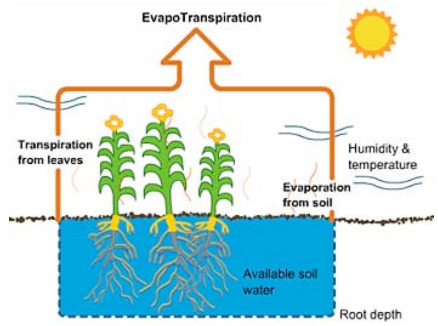


Overview of Remote Sensing and Earth System Modeling

Week 2

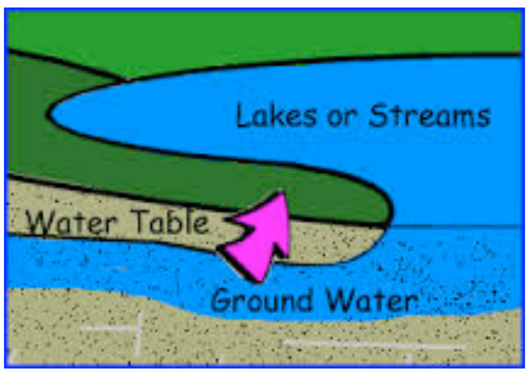
Rainfall and Run Off

Week 3



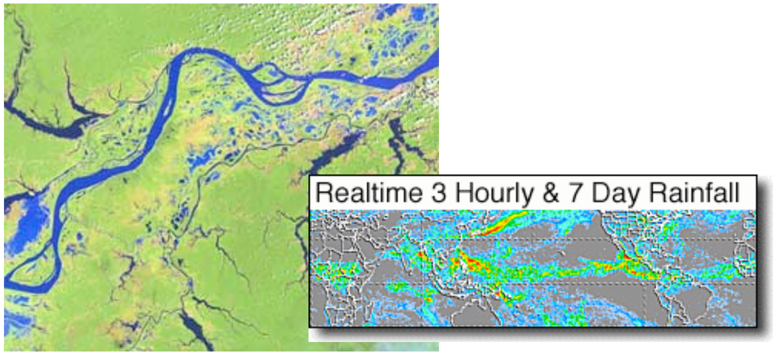
Soil Moisture and Evapotranspiration

Week 4



Reservoir and Ground Water

Week 5



Web-tools for Data Access/Imaging

Week 1 (17 October 2013)

Overview of NASA Remote Sensing and Earth Systems Modeling Data for Water Resources Management

- Strengths and Limitations of Remote Sensing and Model-based Data

- Fundamentals of Remote Sensing and Introduction to Atmosphere-Land Models

- Satellites, Sensors, and Models for Water Cycle Components

Earth’s Water Resources

Where is Earth’s Water?

Approximately 1.3 Billion cubic km of water in oceans

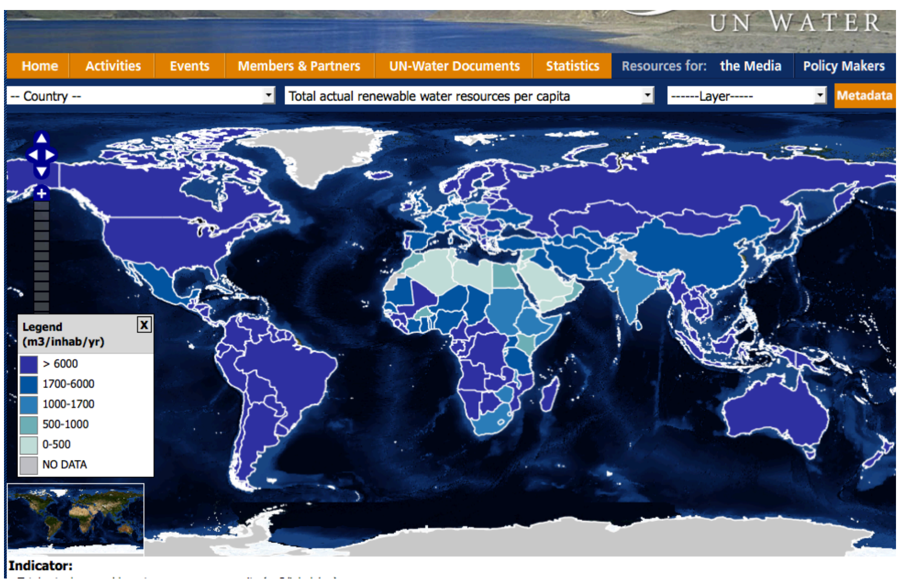
2120 cubic km in rivers

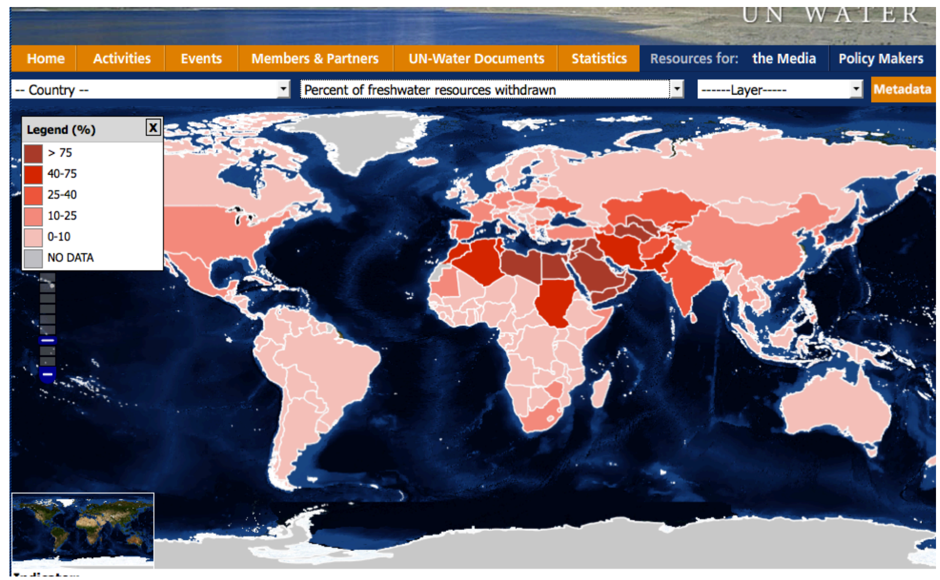
Only 2.5% of earth’s total water is Freshwater

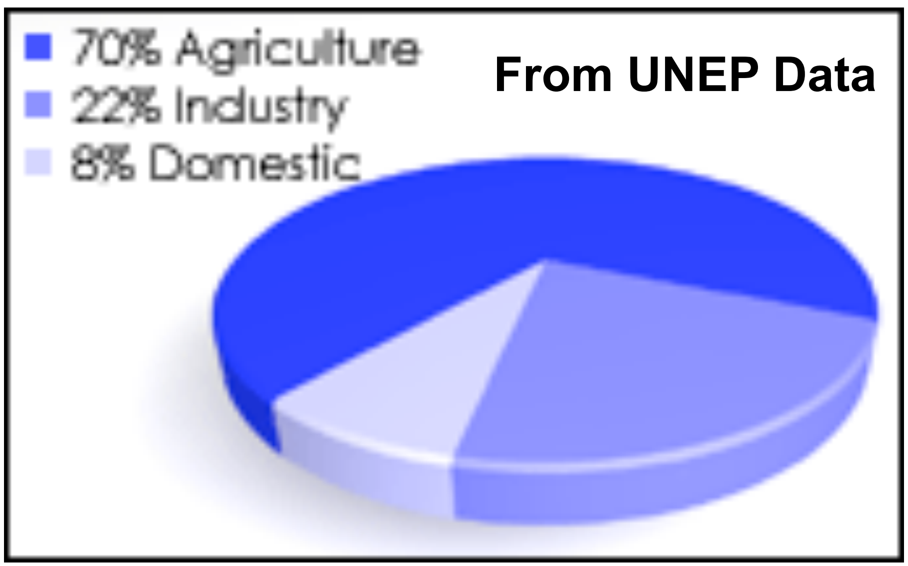
Only 1.3% of that is surface water

From USGS: http://ga.water.usgs.gov/edu/earthwherewater.html

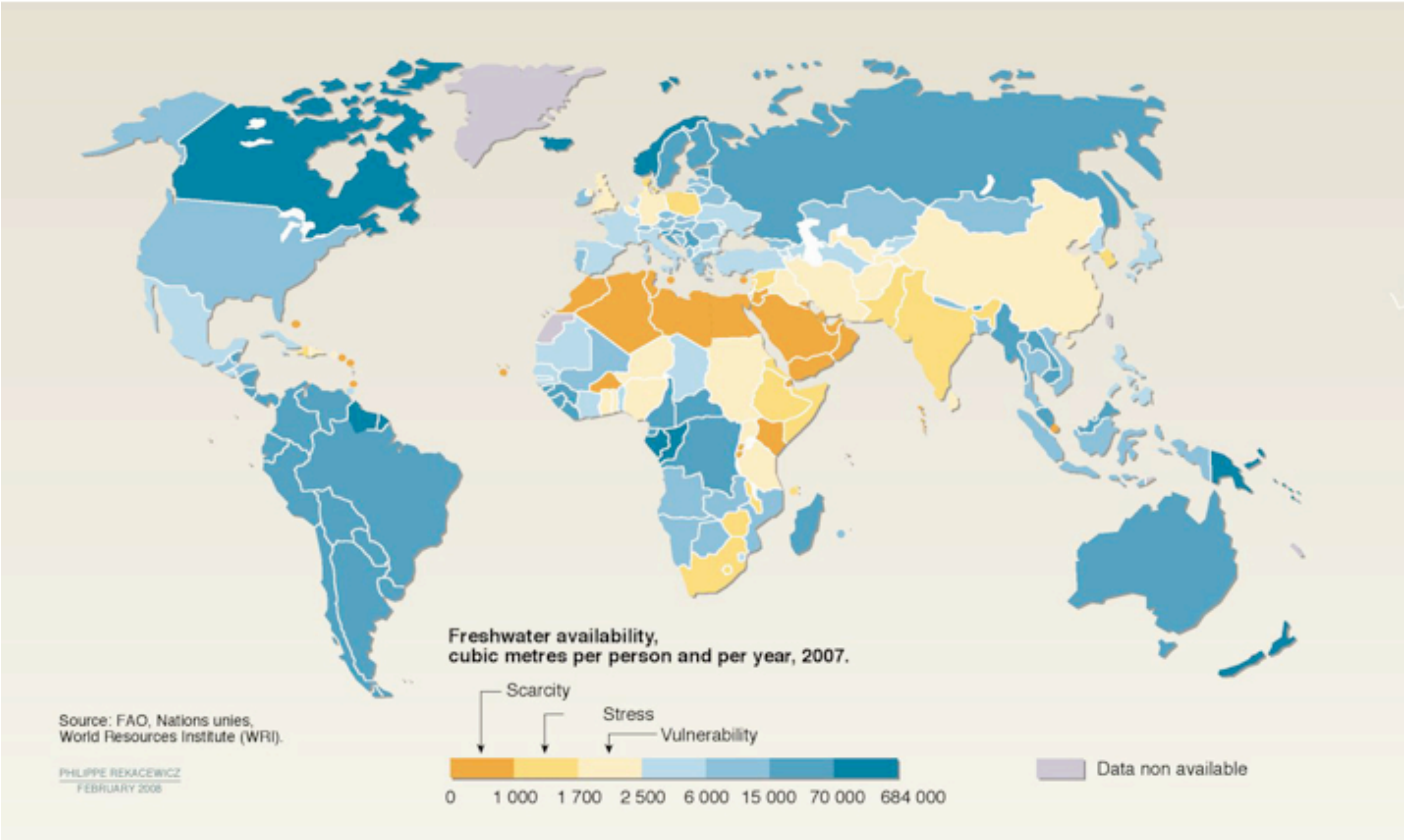
Fresh Water Withdrawal/Usage



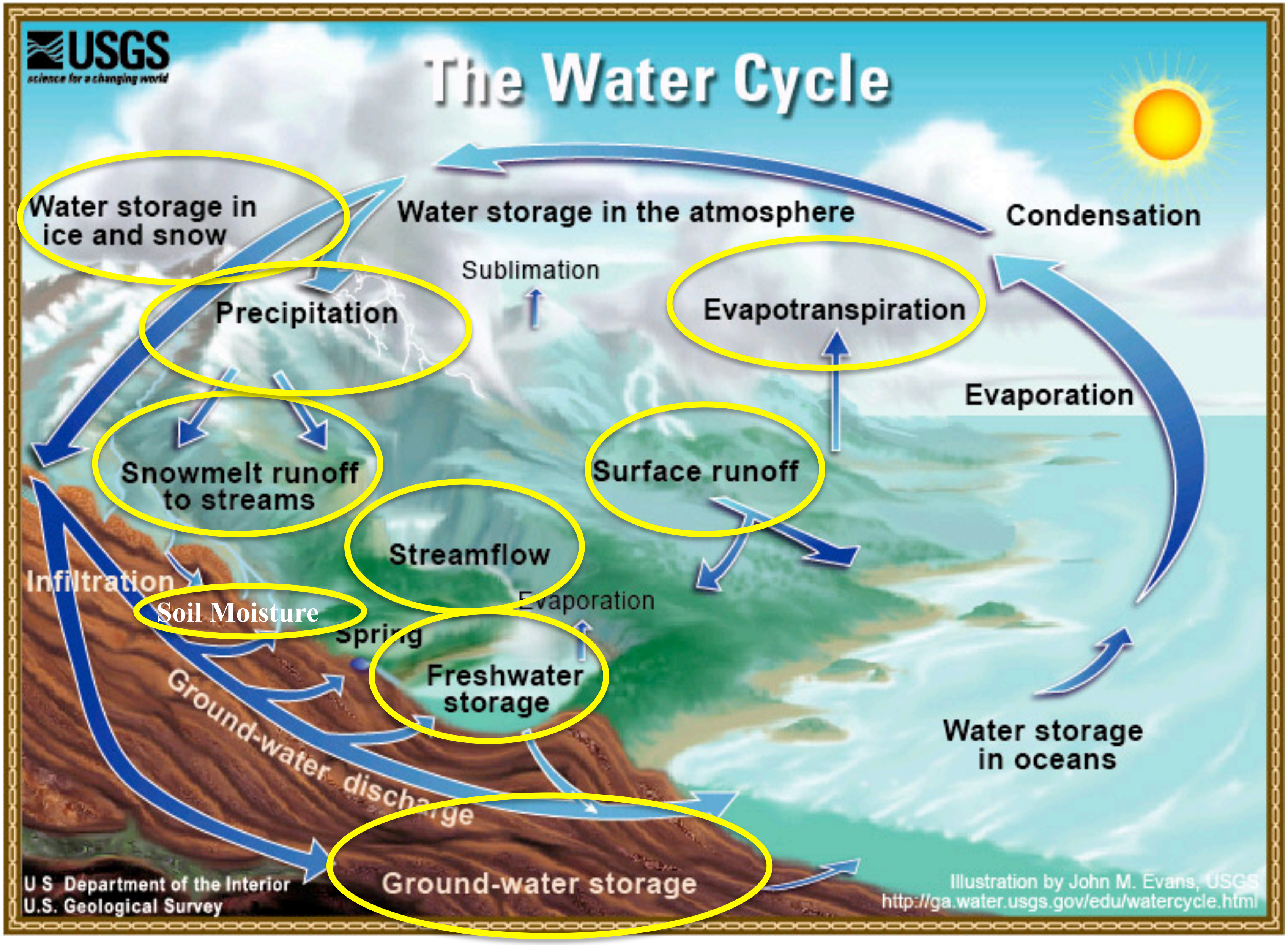




Global Freshwater Availability Per Capita in 2007



Fresh Water Components



Water Resources Management

- Requires balancing Fresh Water availability and usage
- **Precipitation (rain, snow)** is the main source of Fresh Water – regionally, **streamflow, lakes, soil moisture, and ground water** also contribute to available Fresh Water
- **Evaporation and Evapotranspiration** contribute to the loss of water to the atmosphere and the depletion of available Fresh Water
- Fresh Water usage changes regionally according to population, agricultural, and industrial practices
- There is substantial spatial and temporal variability in these factors due to natural (e.g. weather and climate variability) and human-induced influences (e.g. climate change, land use, population change)

Water Resource Management

- Sustainable use of available Fresh Water – **requires accurate, quantitative knowledge of the water cycle components**

Water Resource Information

- Not all water cycle components can be easily measured directly (e.g. evapotrasnpiration, run off, water vapor transport)

- NASA Satellites and Earth Systems Models measure/calculate All Water Cycle Components

NASA Satellites and Earth Systems models provide global scale water cycle quantities on hourly, daily, seasonal, and multi-year time scales useful for water resource management

- Rain
- Temperature
- Humidity
- Winds
- Soil Moisture
- Snow/Ice
- Clouds
- Terrain
- Ground Water
- Vegetation Index
- Evapotranspiration
- Run off

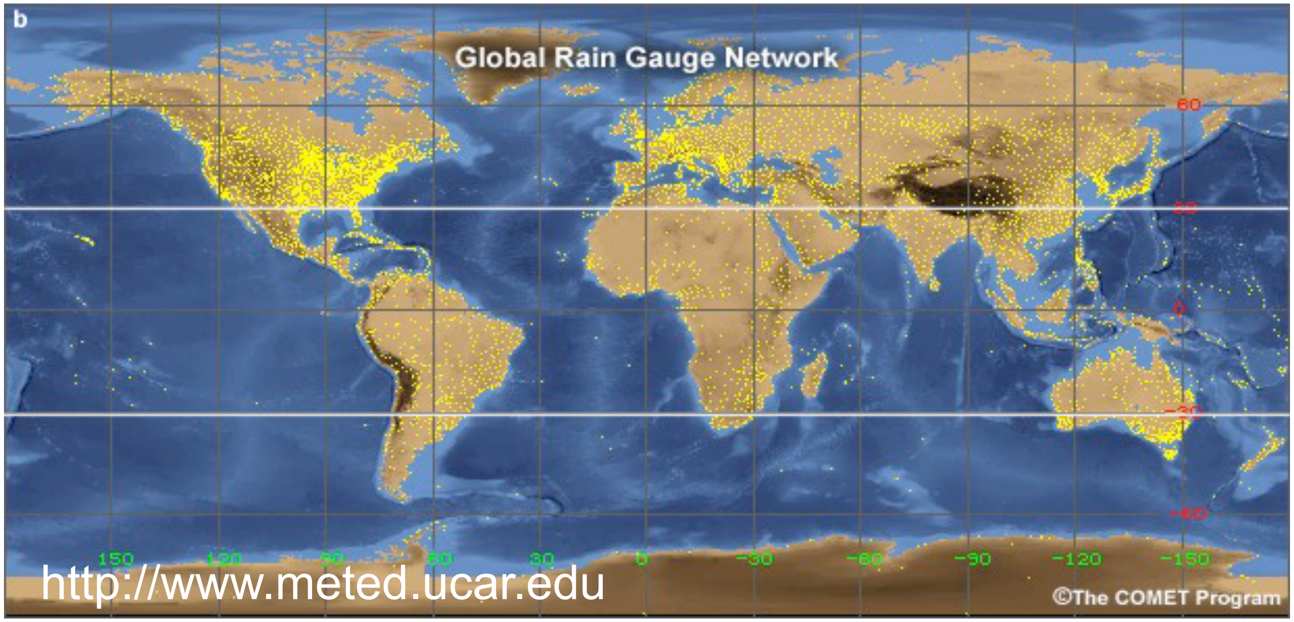
Water resources management over land need :

Rain amount
Snow/Ice, Snowmelt amount
Run off
Soil moisture
Evapotrasnpiration
Ground water

All other quantities are available from satellite observations as well as from models
Quantities in green are derived from satellite observations
Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

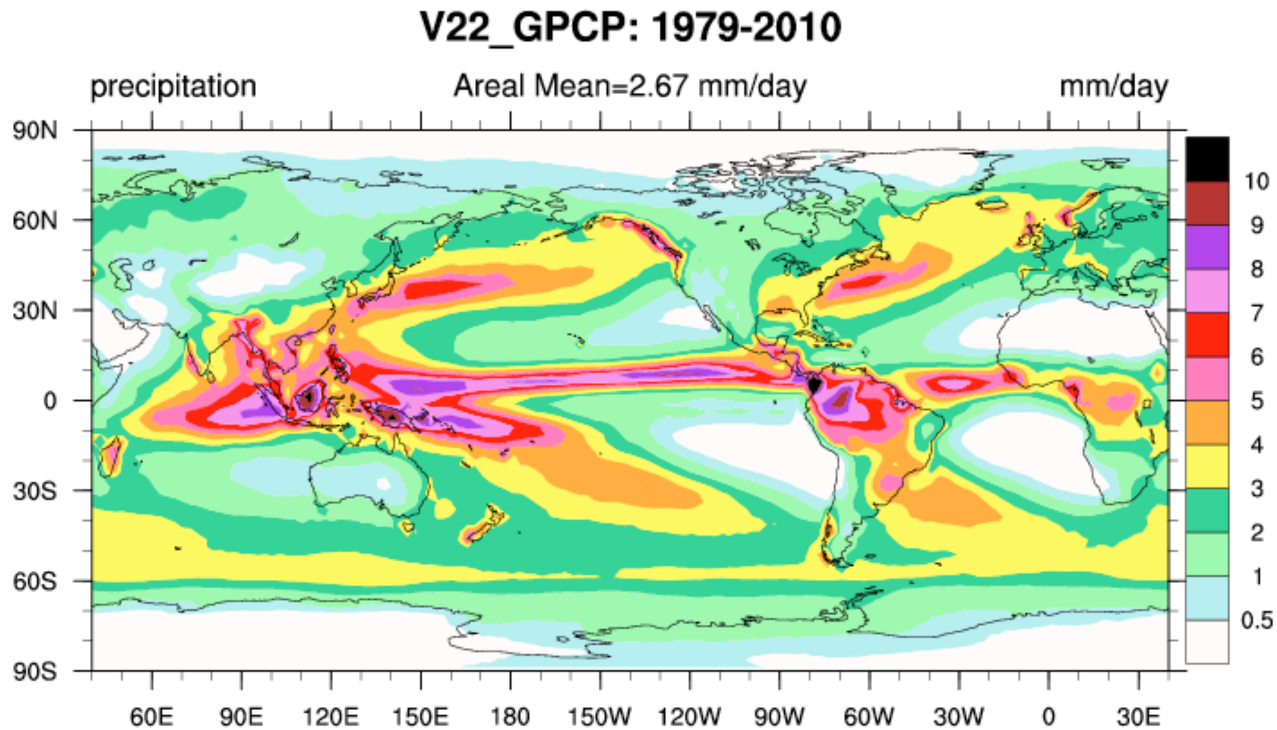
Advantages of Remote Sensing observations

Surface-based Raingauge Measurements



- Non-uniform spatial and temporal coverage
- Measurements not always consistent among instruments
- Inadequate for assessing global rainfall and its variability due to climate conditions

Remote Sensing observations



Rainfall Estimates Combined from Multiple International Satellites

- Provide information where there are no ground-based measurements, including over oceans
- Provide globally consistent observations

Remote Sensing observations provide large scale perspective

GOES Satellite Image of Hurricane Katrina

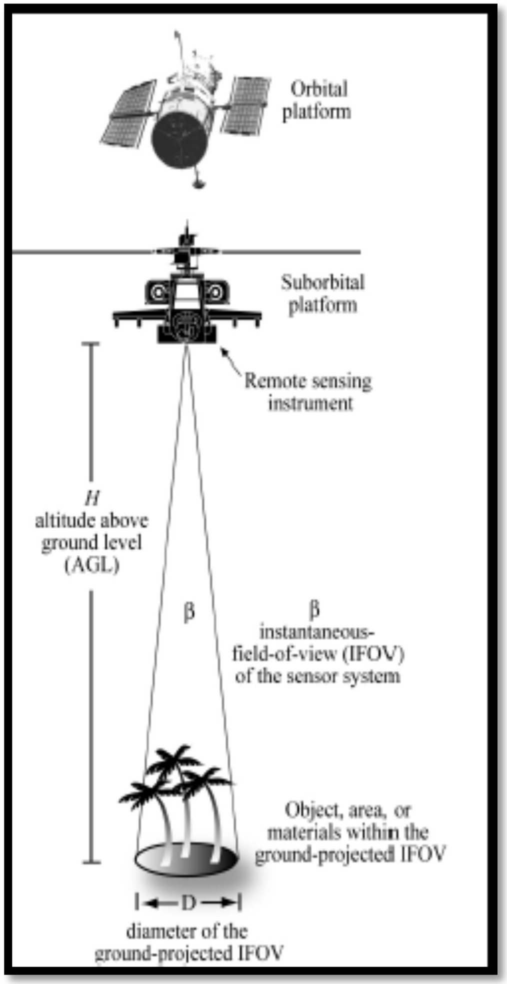
Fundamentals of Remote Sensing

Remote Sensing

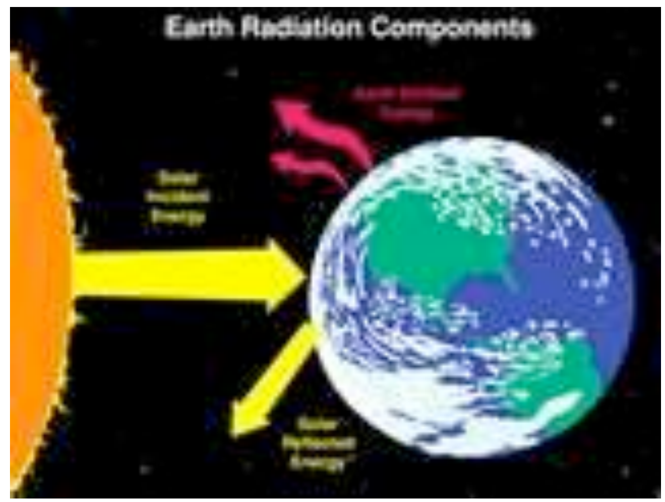
Measurement of a quantity associated with an object by a device not in direct contact with the object

- Platform depends on application
- What information? how much detail?
- How frequent

Satellite Remote Sensing: measuring properties of the earth-atmosphere system from space

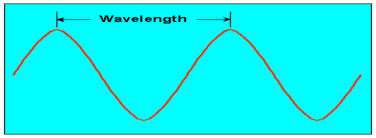


Satellites carry instruments or sensors which **measure electromagnetic radiation** coming from the earth-atmosphere system

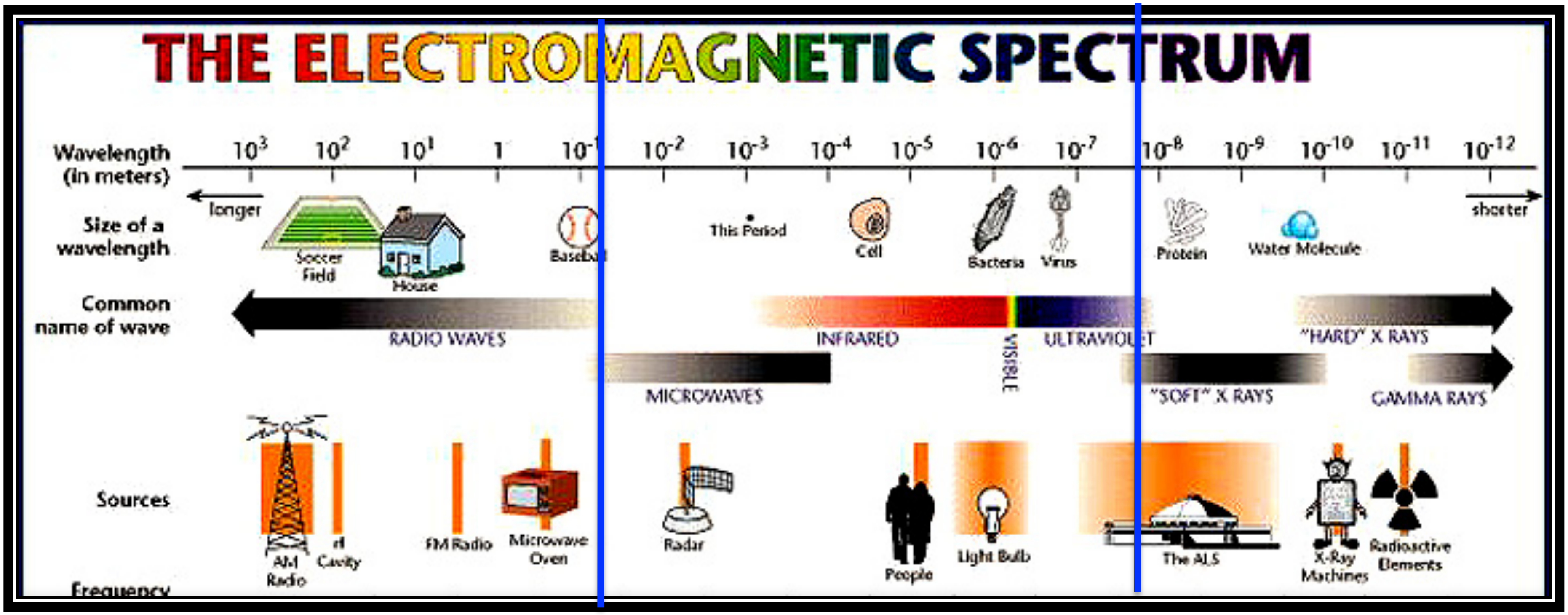


Electromagnetic Radiation

Earth-Ocean-Land-Atmosphere System :
- reflects solar radiation back
- emits Infrared radiation and Microwave radiation



Electromagnetic waves

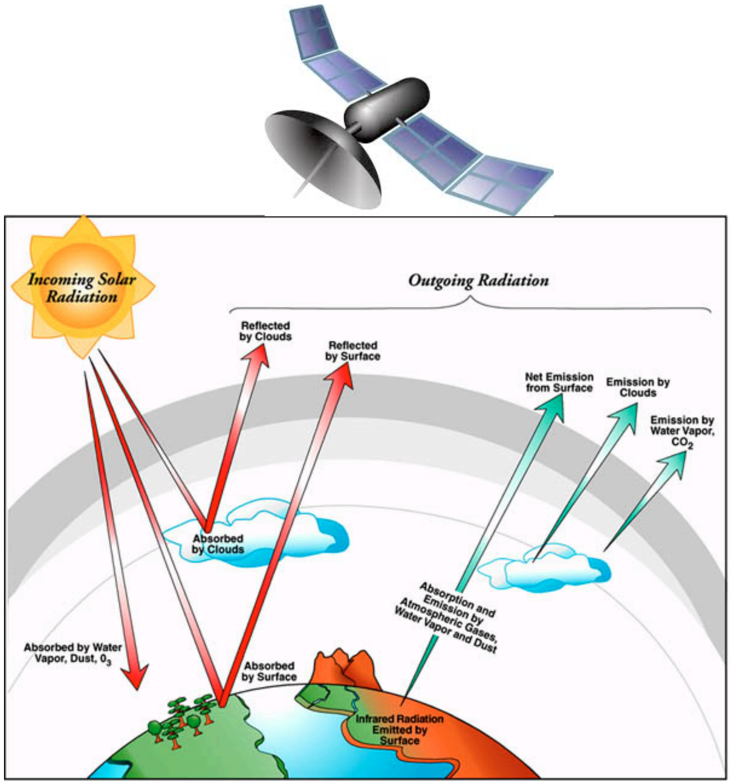


Satellite Remote Sensing

Measuring Properties of Earth-Atmosphere System from Space

- The intensity of reflected and emitted radiation to space is influenced by the surface and atmospheric conditions

- Thus, satellite measurements contain information about the surface and atmospheric conditions



Satellite Remote Sensing Observations

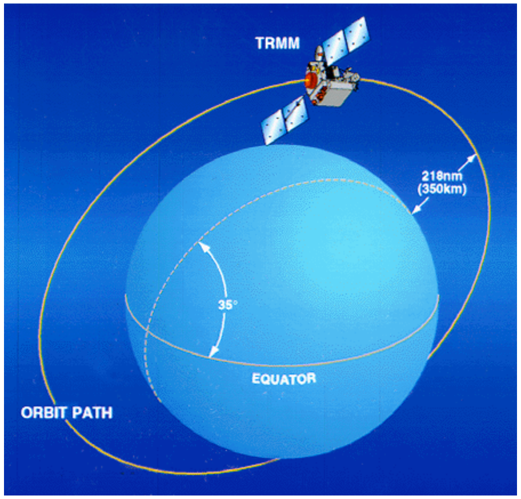
What you need to know:

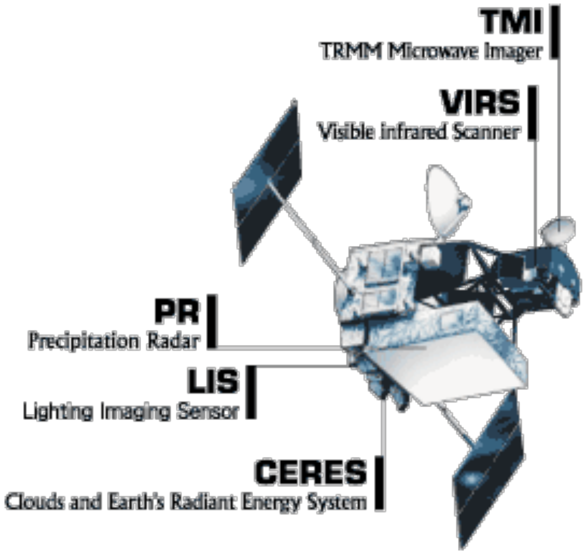
- Instruments/sensors and types
- Types of satellite orbits around the earth
- Spatial and Temporal Resolution and Spatial Coverage
- Geophysical quantities derived from the measurements

  quality and accuracy of the derived quantities

  availability, access, format

  applications and usage





Satellite Sensors

Type of Sensors

Spatial Resolution

Temporal Resolution

Spectral Resolution

Radiometric Resolution

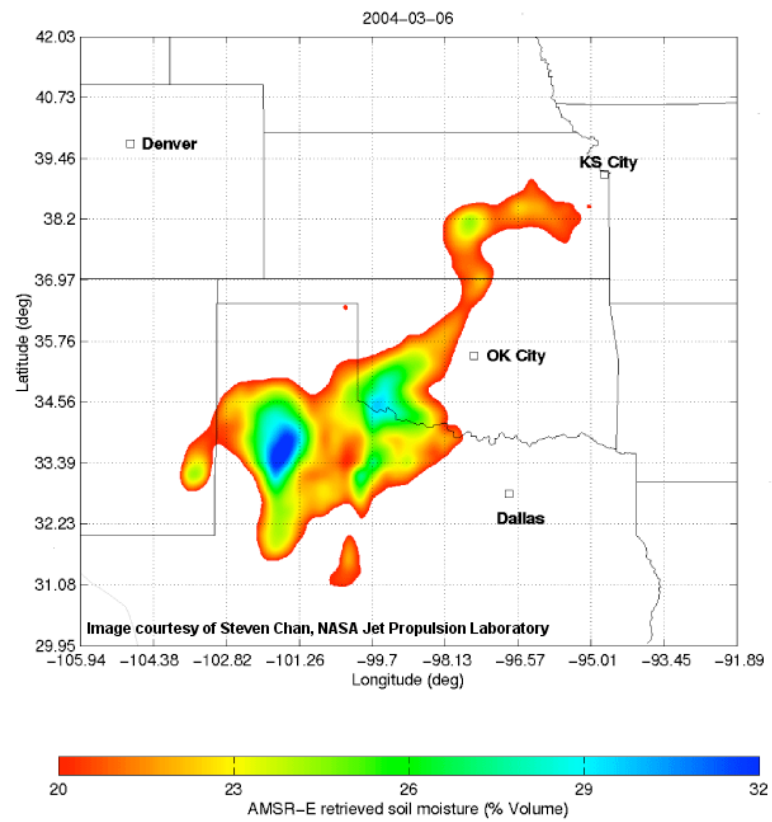
Satellite Sensors

Passive remote sensors
Measure radiant energy
Reflected or emitted by the
earth-atmosphere System

Radiant energy is converted to
geophysical quantities

Examples:
TMI, AMSR, AIRS, MODIS

Soil Moisture



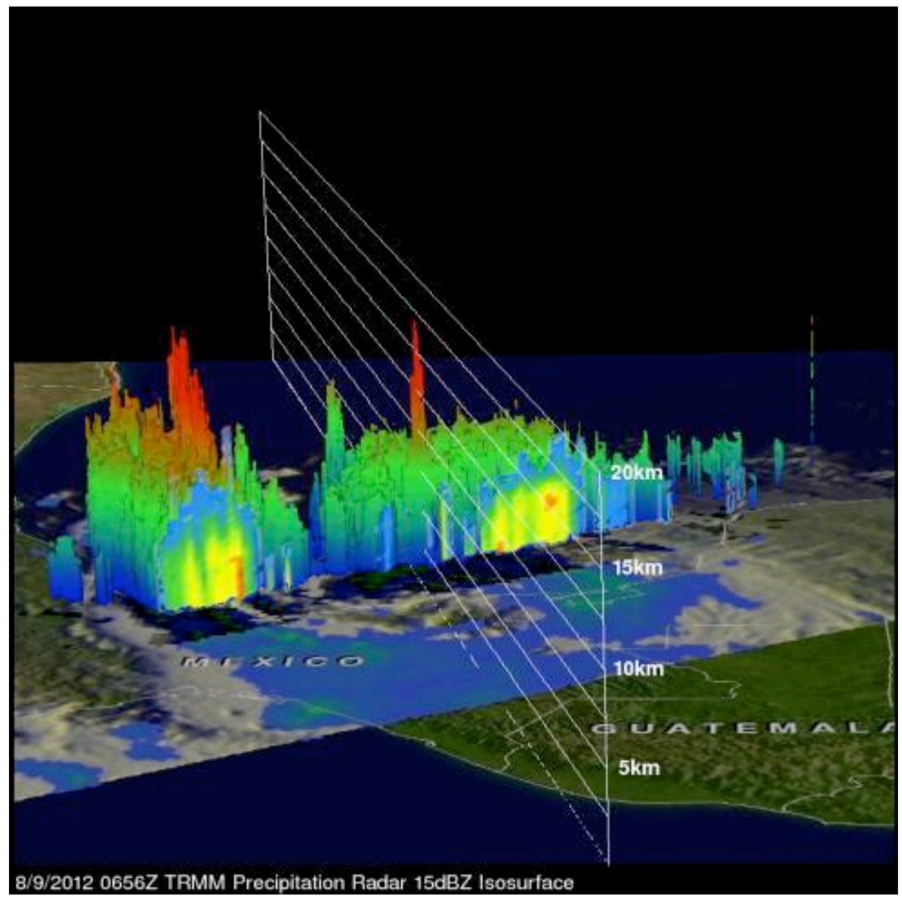
Satellite Sensors

Active remote sensors ‘throw’ beams of radiation on the earth-atmosphere system and measure ‘back-scattered’ radiation

The back-scattered radiation is converted to geophysical parameters

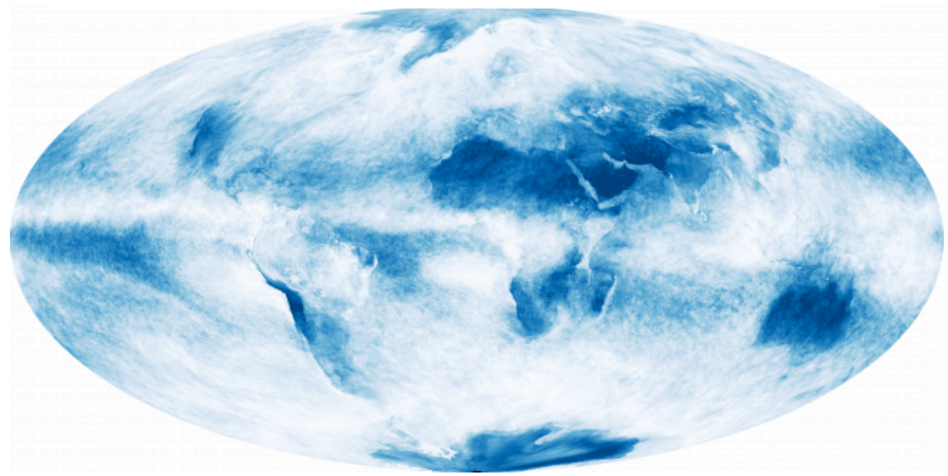
Examples: Precipitation Radar, LIDAR,

TRMM satellite – **Precipitation Radar, an active sensor,** measuring 3-dimensional reflectivity converted to rain rates for Hurricane Ernesto (August 9, 2012)



Satellite Sensors

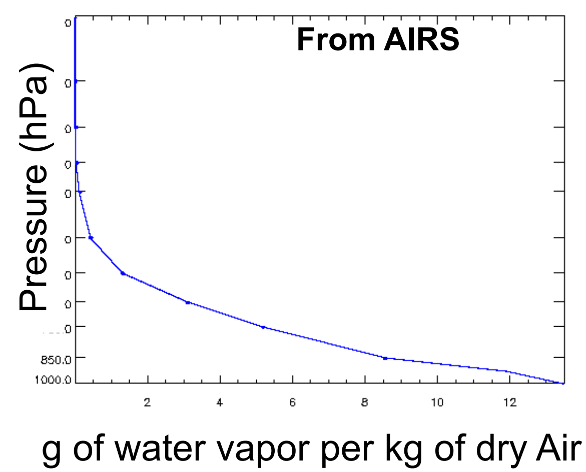
Cloud Image for October 2009 from MODIS



Imagers: Create Images

Examples: MODIS, TMI

Water Vapor Profile Averaged over Central US for July 2012



Sounders: Provide vertical profiles

Examples: AIRS

Spatial and Temporal Resolution of Satellite Measurements

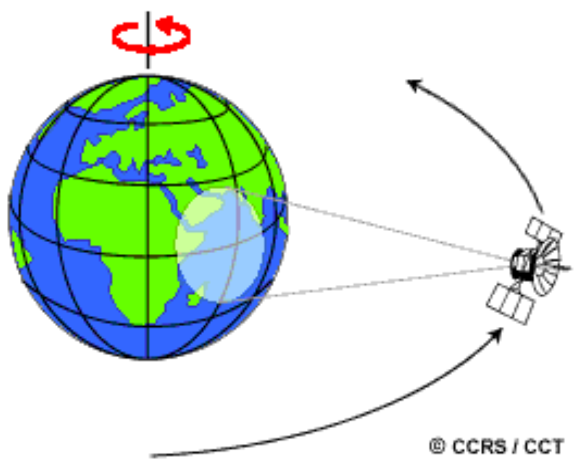
- Depends on the satellite orbit configuration and sensor design.

- **Temporal resolution:**
  How frequently a satellite observes the same area of the earth

- **Spatial Resolution:**
  Decided by its pixel size -- pixel is the smallest unit measured by a sensor

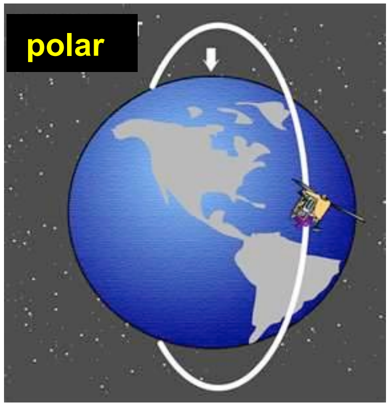
Types of Satellite Orbits

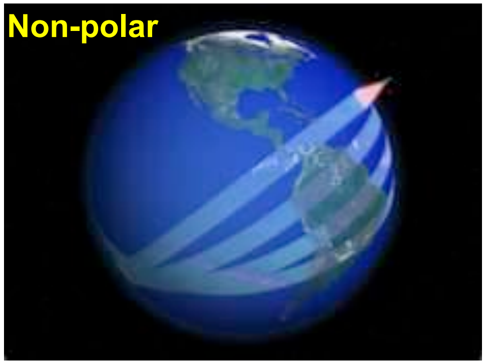
Geostationary orbit



Satellite is at ~36,000 km above earth at equator. Same rotation period as earth's. Appears 'fixed' in space.

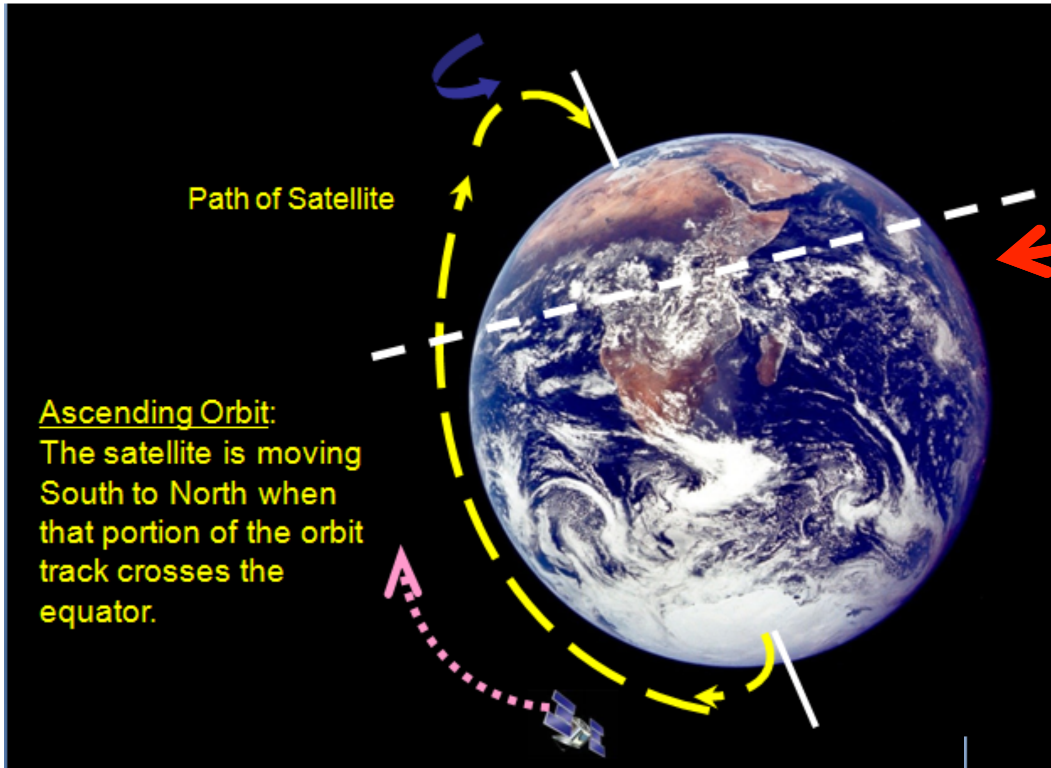
Low Earth Orbit (LEO)

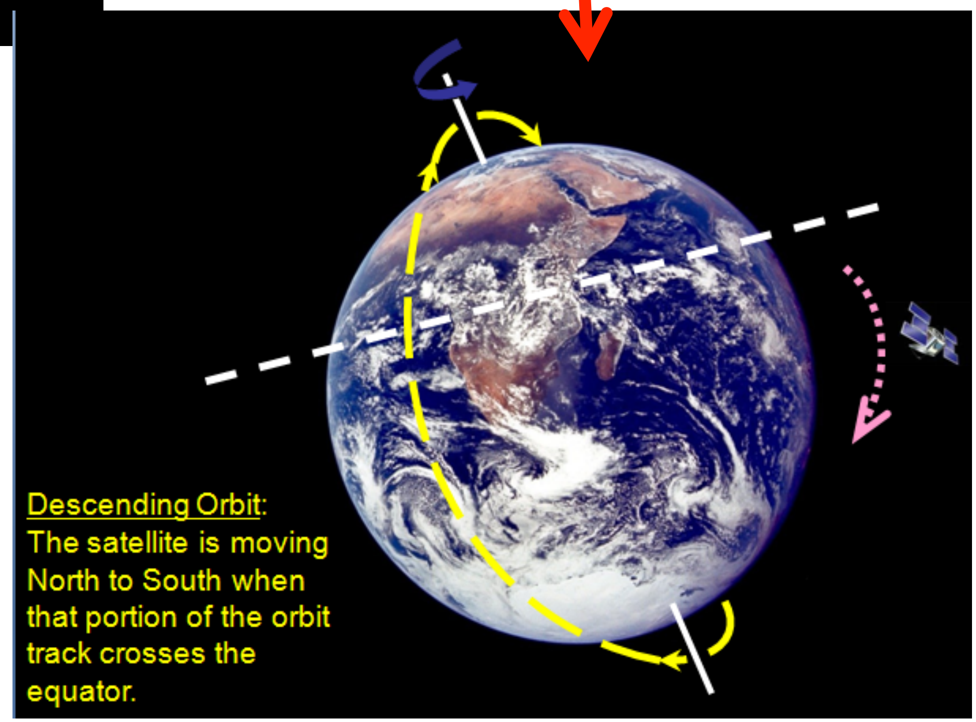




Circular orbit constantly moving relative to the Earth at 160-2000 km. Can be in Polar or non-polar orbit

Ascending vs Descending

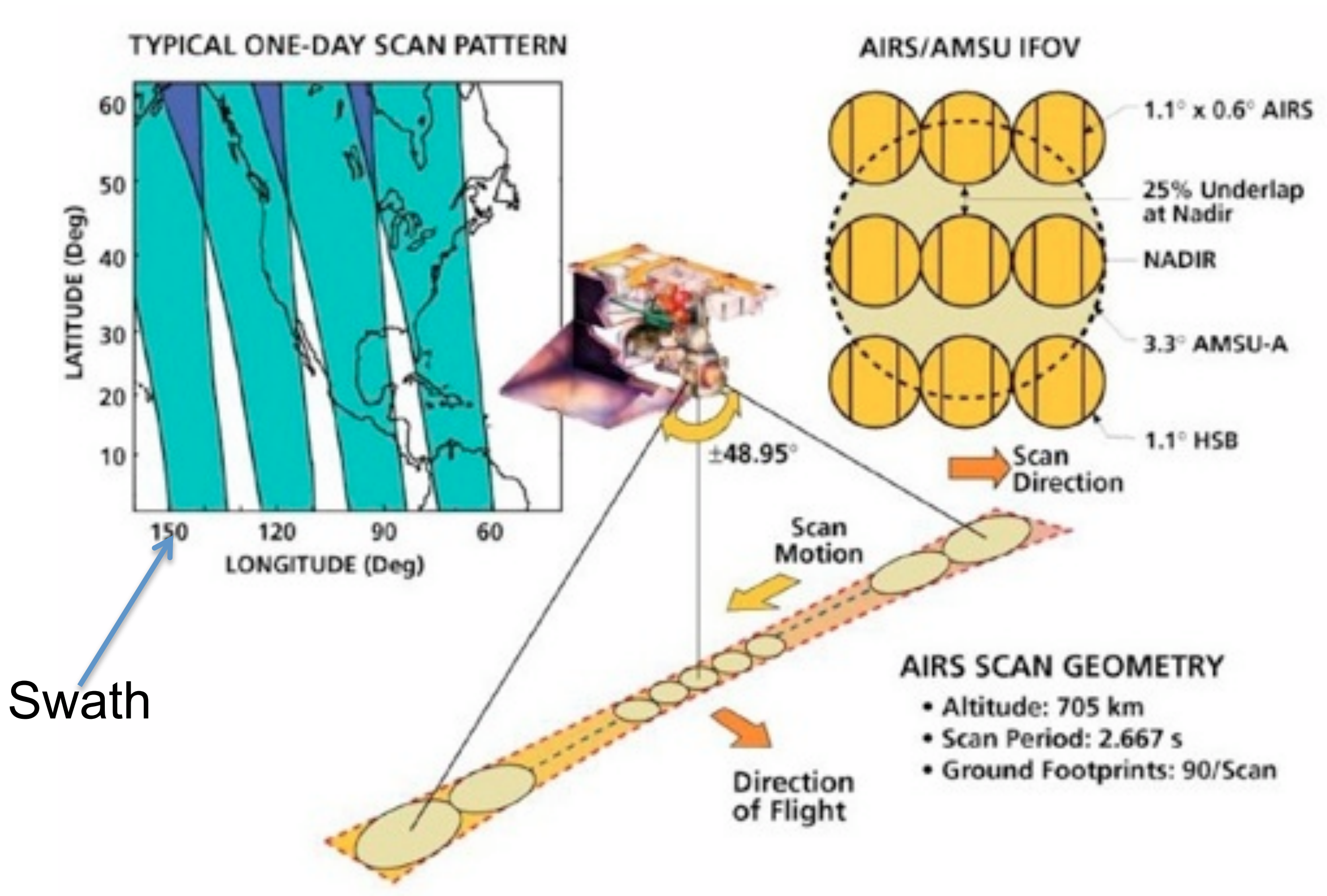




Polar Orbits

Spatial resolution

Example (Atmospheric Infrared Sounder)



AIRS is flying on-board NASA's Aqua satellite

Spatial resolution

Important for information retrieval

Pixel size 10m

Pixel size 20m

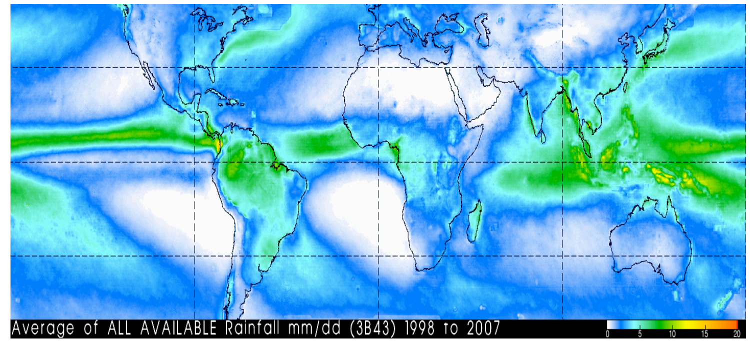
Pixel size 40m

Pixel size 80m

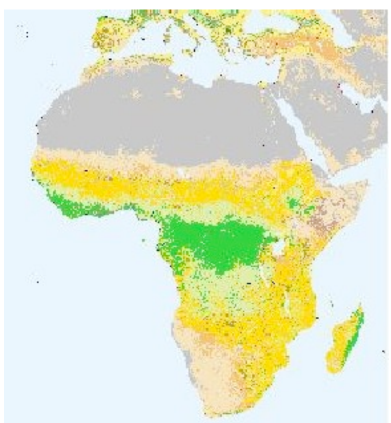
NASA Satellites Measurements with Different Spatial Resolution

Landsat Image of Philadelphia
Spatial resolution: 30 m

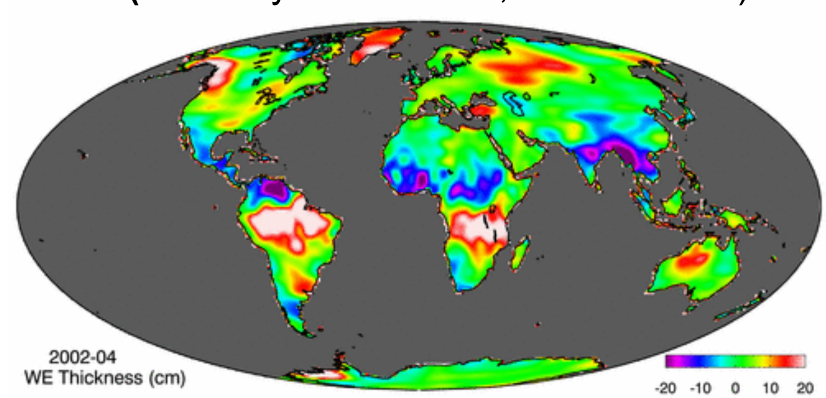
Rain Rate from TRMM
Spatial resolution: 25 km²



Land Cover from Terra/MODIS:
Spatial resolution: 1 km²
(From: http://gislab.jhsph.edu/)



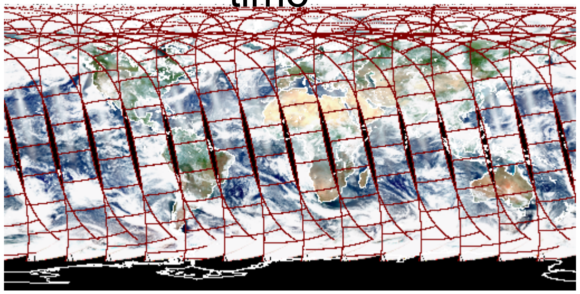
Terrestrial Water Storage Variations from GRACE: Spatial resolution: 150,000 km² or coarser (Courtesy: Matt Rodell, NASA-GSFC)



Spatial Coverage and Temporal Resolution

Polar orbiting satellites: global coverage - but one to two or less measurements per day per sensor. Orbital gaps present. Larger Swath size, higher the temporal resolution.

Aqua (“ascending” orbit) day time



Non-Polar orbiting satellites: Less than one per day. Non-global coverage. Orbital gaps present. Larger Swath size, higher the temporal resolution.

TRMM Image

Geostationary satellites: multiple observations per day, but limited spatial coverage, more than one satellite needed for global coverage.

GOES Image

Spectral Resolution: The number and width of spectral channels. More and finer spectral channels enable remote sensing of different parts of the atmosphere

Radiometric Resolution: Remote sensing measurements represented as a series of digital numbers – the larger this number, the higher the radiometric resolution, and the sharper the imagery.

Remote Sensing Observations
Trade Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolution at the same time
- Several sensors can obtain global coverage every one – two days because of their wide swath width
- Higher resolution polar/non-polar orbiting satellites may take 8 – 16 days to attain global coverage.
- Geostationary satellites obtain much more frequent observations but at lower resolution due to the much greater orbital distance.

NASA Satellites and Sensors for measuring the Water Cycle Components

NASA Satellites for Water Quantities

Landsat (07/1972-present)

TRMM (11/1997-present)

Terra (12/1999-present)

Aqua (5/2002-present)

GRACE (3/2002-present)

TRMM: Tropical Rainfall Measuring Mission
GRACE: Gravity Recovery and Climate Experiment

NASA Remote Sensing Quantities for Water Resources Management

Satellite	Sensors	Quantities
TRMM	**Precipitation Radar (PR)** **TRMM Microwave Imager (TMI)** **Visible Infrared Scanner (VIRS)**	Rain Rate, Vertical Rain Rate Profile, Accumulated Rain
Terra and Aqua	**MODerate Resolution Imaging Spectroradiometer (MODIS)**	Snow Cover, Vegetation Index, Leaf Area Index, Land Cover
Aqua	Atmospheric Infrared Sounder (AIRS) Advanced Microwave Scanning Radiometer for EOS (AMSR-E)	3-dimensional Atmospheric Temperature and Humidity Snow Water Equivalent, Sea Ice, Soil Moisture, Rain Rate
Landsat	(Enhanced) Thematic Mapper (ETM)	Vegetation Index, Leaf Area Index, Land Cover
Grace	K-Band Ranging Assembly	Terrestrial Water

Satellite Products
Limitations

- There are multiple sources of the same products, with varying spatial/temporal resolutions and accuracies

- There are many assumptions and approximations in going from raw data to specific quantity such as rain amount

- Data quality can range from excellent to poor depending on:
  - Instrument capabilities
  - Instrument calibration and performance
  - The algorithms used to interpret the data

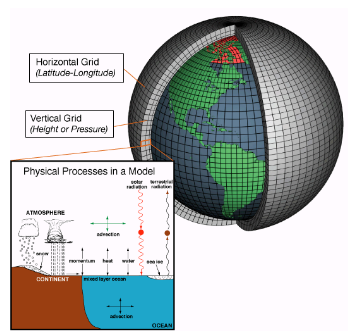
NASA Model-derived Water Cycle Components

Value-added Information

Remote Sensing + Surface Observations + Numerical Models

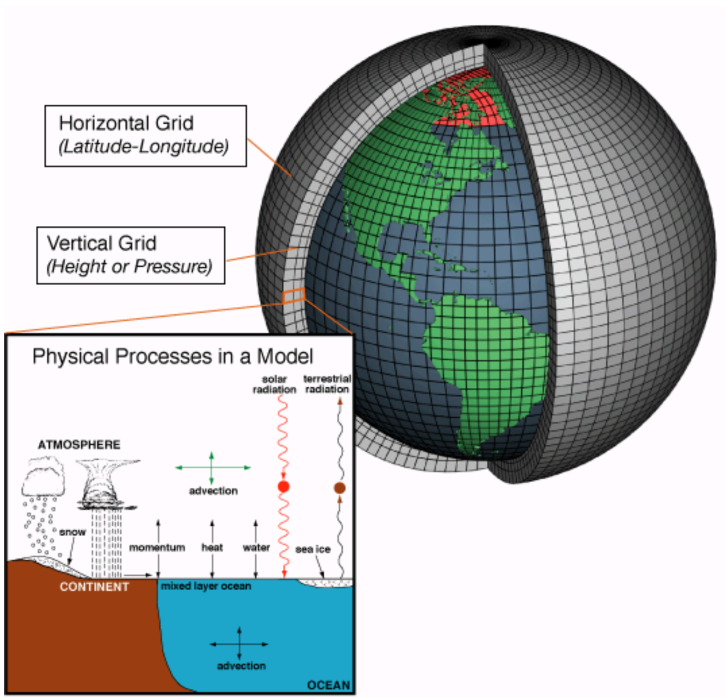
Satellite
Data

surface Measurements
and In-Situ Data



Numerical
Models

Modeling of the atmosphere-Land-Ocean Systems



- Models use the Laws of physics in terms of mathematical equations to represent the atmosphere, ocean, and land systems
- Applied on horizontal and vertical grids by using numerical methods
- **Models use observations to represent the atmosphere-ocean-land system** at a given time to deduce how the system will evolve over space/time
- Models use physical/statistical/empirical techniques to represent environmental processes

NASA Models for Weather, Climate, and Water Resources Quantities

(Atmosphere-Ocean-Land Models)

- GEOS-5 : The Goddard Earth Observing System Version 5
- MERRA: Modern Era Retrospective-analysis for Research and Application
- GLDAS : Global Land Data Assimilation System
- NLDAS : North American Land Data Assimilation System

NASA Models for Water Quantities

Models	Quantities
MERRA	3-dimensional Winds, Temperature, Humidity, Clouds, Rain Rate ,Snow Mass, Snow Cover, Snow Depth, Surface Snowfall Rate, Evapotranspiration
GLDAS/NLDAS	Evapotraspiration, Multi-layer Soil Moisture, **Rainfall**, Snowfall Rate, Snow Melt, Snow-Water Equivalent, Surface and Sub-surface Runoff

Model-derived Quantities
Trade-offs

- Help blend remote sensing and in situ observations – provide geophysical variables on uniform spatial latitude-longitude grids, and at regular intervals.

- Provide variables which are not directly observable, for example, 3-D humidity movement in the atmosphere

- Help understand water cycling processes in the climate system and provide prediction capability

- Use many approximations and assumptions in representing physical processes – as good as our understanding

- There are multiple models, with varying spatial/temporal resolutions and accuracies.

NASA Remote Sensing and Model-derived Water Resource Quantities

- NASA remote sensing and model-based data are **FREE**
- Web-based tools are available for data access, download, and analysis.
- There are numerous observed and model data to choose from according to the application of interest.
- The ARSET Team works with organizations to provide 'hands-on' trainings that facilitate the use of NASA data and decision support tools.

Coming up next week!

Week 2 (24 October 2013)

Overview of Precipitation, Run Off, and Streamflow Data

Thank You!

Amita Mehta amita.v.mehta@nasa.gov